USAARL Report No. 95-28

U.S. Army Aviation Epidemiology Data Register: Incidence of Color Vision Deficiency Among U.S. Army Aviators

By

Kevin T. Mason
Samuel G. Shannon

and

Michael J. Slattery

Aircrew Protection Division

April 1995

U.S. Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577

Notice

Qualified requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), Cameron Station, Alexandria, Virginia 22314. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of address

Organizations receiving reports from the U.S. Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

Destroy this document when it is no longer needed. Do not return it to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

Reviewed:

KEVIN T. MASON
LTC, MC, MFS
Director, Aircrew Protection
Division

ROGER W. WILEY, O.D., Ph.D.
Chairman, Scientific
Review Committee

Released for publication:

for DENNIS F. SHANAHAN
Colonel, MC, MFS
Commanding

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release, distribution unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
USAARL Report No. 95-28

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
U.S. Army Aeromedical Research Laboratory

6b. OFFICE SYMBOL *(If applicable)*
MCMR-UAD

7a. NAME OF MONITORING ORGANIZATION
U.S. Army Medical Research and Materiel Command

6c. ADDRESS *(City, State, and ZIP Code)*
P.O. Box 620577
Fort Rucker, AL 36362-0577

7b. ADDRESS *(City, State, and ZIP Code)*
Fort Detrick
Frederick, MD 21702-5012

8a. NAME OF FUNDING / SPONSORING ORGANIZATION

8b. OFFICE SYMBOL *(If applicable)*

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS *(City, State, and ZIP Code)*

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
62787A	30162787A878	HC	144

11. TITLE *(Include Security Classification)*
U.S. Army Aviation Epidemiology Data Register: Incidence of color vision deficiency among U.S. Army aviators

12. PERSONAL AUTHOR(S)
Mason, Kevin T., Shannon, S. G., and Slattery, M. J.

13a. TYPE OF REPORT
Final

13b. TIME COVERED
FROM TO

14. DATE OF REPORT *(Year, Month, Day)*

15. PAGE COUNT

16. SUPPLEMENTAL NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
06	05	
12	06	

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
database, epidemiology, aviator, color blindness, color vision deficiency

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

The Chief, Visual Sciences Branch, U.S. Army Aeromedical Research Laboratory, requested a determination of the incidence of color vision deficiency among Army aviators. As we enter the next century, the color vision requirements of Army aviators will increase with the introduction of multicolored displays.

Since aviator training applicants are disqualified routinely from training due to color vision deficiency, there should be no aviators with color vision deficiency. However, this paper details incidents of exception to policy for known color vision deficiency, acquired color vision deficiency, and aviation medicine clinic screening program failures due to poor methods or deception by applicants and conspirators. The in-flight evaluation of aviators discovered to have color vision deficiency is described.

(Continued on next page)

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL
Chief, Science Support Center

22b. TELEPHONE *(Include Area Code)*
(334) 255-6907

22c. OFFICE SYMBOL
MCMR-UAX-SS

DD Form 1473, JUN 86 — *Previous editions are obsolete.*

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. Abstract (Continued):

The incidence of color vision deficiency was determined by a review of records in the U.S. Army Aviation Epidemiology Data Register (AEDR), to include archived aeromedical board documents, for the period of calendar years 1982 to 1992. Color vision deficiency among Army aviators is rare with an incidence of about one new case per 10,000 aviator-years per year. Two of twenty-nine were granted exceptions to policy to complete flight training with color vision deficiency. The others (27 of 29) were granted administrative waivers to continue flying duties with their condition. Only half of the color vision deficient aviators underwent ophthalmology or optometry consultation. Only 17 percent (5 of 29) underwent an attempt to discover the axis of color vision deficiency. Only 59 percent (17 of 29) underwent in-flight evaluations, despite the longstanding aeromedical policy requirement for all aviators with color vision deficiency to undergo in-flight evaluations.

The authors make multiple recommendations to visual scientists and to aeromedical policy and standards decision makers.

Table of contents

Page

List of tables 1

Military relevance 3

Background 3

Screening for color vision deficiency 3
Screening aviation training applicants 3
Exceptions to policy 3
Acquired versus congenital color vision deficiency 4
Screening program failure 5
Screening trained aviators by inflight evaluation 6

Method 6

Results 6

Discussion 7

Conclusions and summary 9

References 10

Other relevant references not cited 12

List of tables

Table

1. A comparison of acquired and congenital color vision deficiency 4

2. Incidence of color vision deficiency waivers per 1,000 aviator-years by calendar year 7

3. Findings among the color vision deficient subjects 8

This page was left blank intentionally

Military relevance

Chief, Visual Sciences Branch, U.S. Army Aeromedical Research Laboratory, requested an epidemiologic survey of color vision deficiency among U.S. Army aviators. Color vision requirements for Army aviators are more complex as new cockpit systems rely on multicolored displays. The analysis was based on historical data contained in the U.S. Army Aviation Epidemiology Data Register (AEDR).

Background

Screening for color vision deficiency

Screening applicants to flight training

Aviator training applicants are screened for color vision deficiency during the initial flying duty medical examination (FDME). Those with 5 or more errors on the 14-plate pseudoisochromatic plate series (PIP), and/or those with any errors on the 9 test pairs of the Farnsworth lantern (FALANT) are disqualified for entry into training (Department of the Army, 1995; Mason, 1995). An unknown number of potential applicants with color vision deficiency are not reported to the central FDME review process. Advisors may tell them to not bother applying to flight training. A flight surgeon may do an informal screening and advise the applicant to not pursue the application process further. So the exact prevalence of color vision deficiency among applicants is unknown.

Failure to meet color vision screening standards is considered a major medical disqualification for Army aviator training. It is presumed that all Army aviators with color vision deficiency either have an exception to policy to enter flight training with a known color vision deficiency, have acquired color vision deficiency, or were screening program failures due to poor screening methods by the FDME examiners or deception by the applicant or other conspirators.

Exceptions to policy

Exceptions to policy (ETP) are given to exceptional applicants who have minor, stable medical disqualifications for entry into flight training. For example, hemoglobinopathy and anemia are disqualifying. But one hemoglobinopathy, beta thalassemia minor, is unlikely to progress, decrease operational performance, or cause incapacitation. A cadet, in the upper tenth percentile of achievement in academic, physical, and military training, may have beta thalassemia minor with mild anemia. An ETP might be considered for this exceptional individual and circumstance. In the case of congenital color vision deficiency, the condition is stable, but presents with many degrees of deficiency that may be operationally significant. Historically, ETPs have been granted rarely for color vision deficiency (3 among an estimated 70,000 applicants from 1982 to 1994, unpublished AEDR data set of the first author). The basis of this decision includes color vision deficient

individuals have a greater risk for mishap at the controls of ground vehicles (Verriest et al., 1980) and aircraft (Dille and Booze, 1979), have reduced visual acuity in certain lighting conditions compared to normals (Adams and Tague, 1985), and have difficulty reacting to, properly identifying, and/or seeing warning colors in the operational environment (Farnsworth, 1946; Sloan and Habel, 1955a; Sloan and Habel, 1955b; Heath and Schmidt, 1959; Nathan, Henry, and Cole, 1964;Watkins, 1971; Steen, Collins, and Lewis, 1973; Vingrys and Cole, 1988). The operational color vision disability is worse in protanopic aircrew compared to deuteranopic aircrew (Ruff and Schmidt, 1940; Heath and Schmidt, 1959; Kuyk et al., 1987).

Acquired versus congenital color vision deficiency

Table 1 shows a comparison of acquired and congenital color vision deficiency (Hart, 1992). Aviators with acquired deficiency require a thorough evaluation to rule out serious underlying conditions. Unfortunately, acquired deficiency is more difficult to detect by PIP and FALANT screening tests since these tests were designed primarily to detect binocular congenital deficiency. Fortunately, aviators with acquired deficiencies are likely to present for evaluation due to worrisome symptoms of changing color vision perception.

Table 1.
A comparison of acquired and congenital color vision deficiency.

Category	Color vision defect	
	Acquired	Congenital
Prevalence in population	<1.0 percent	6-8 percent of men and 0.5 percent of women
Patient complaint	Realize they have lost color discrimination capability, very bothersome	Do not notice lost color perception, unless pointed out to them or they can not perform a color dependent task
Scope of defect	May be monocular and/or affect only a portion of a visual field	Binocular and affects entire visual field
Associated symptoms	Noticeable decrease in visual acuity and/or dark adaptation	Do not always notice decrease in visual acuity. Dark adaptation is normal.
Underlying disorder	Retinal, optic nerve, or visual cortex disease; medication use	Abnormality of retinal photosensitive pigment composition
Axis of defect	Blue-yellow axes affected in addition to red-green axes	Affects predominately red-green axes

The first author evaluated an air traffic controller who complained of loss of color discrimination at night. An air traffic control tower evaluation revealed the controller no longer could identify the aircraft marker lights which gave visual cues as to the type of aircraft and direction of travel. Color vision tests and ocular examination were normal. Evaluation led to a trial of glasses to correct night myopia, which corrected the color vision defect. In another case, an aviator presented with a complaint of a reduction in color vision and visual acuity in one eye. Color vision testing was abnormal in that eye. Further evaluation led to the discovery of glaucoma.

Screening program failure

Screening programs for aircrew members may fail for multiple reasons. Most commonly, screening program failures are due to poor methods, inaccurate recording of results, and fraud. Screening program failures examples are from the following personal experiences of the first author.

A routine inspection of an aviation medicine clinic revealed that the answer to the PIP presentation plate was written in pencil by the medic on the back of the preceding plate as a reminder to the medic of the correct response for the presentation plate. Color vision deficient aviation training applicants can quickly determine the significance of the penciled number and falsely pass the PIP test in this clinic. Other investigators reported this same finding in other clinics.

A flight training applicant knew he was color vision deficient. He consulted his family optometrist who fit one eye with a red-colored, X-Chrom contact lens to enhance the applicant's chance of passing the screening PIP plates. The lens was discovered when the first author performed a slit lamp examination of the applicant during the vision screening session. Use of this lens significantly improves PIP, Dvorine color vision plate, and Farnsworth-Munsell 100-hue color vision test scores; but not FALANT scores (LaBissoniere, 1974; Ditmars and Keener, 1976; Welsh, Vaughan, and Rasmussen, 1978).

An investigation of a series of failed color vision screening tests on the applicant's second FDME, but not on the first FDME, led to the discovery that a majority of these applicants had their first FDME performed at one aviation medicine clinic. The flight surgeon in this clinic admitted that he had a habit of overlooking color vision deficiencies among applicants. If he thought the color vision deficient applicant would otherwise be a "true air warrior," he would transcribe false results on the FDME. The applicants compounded the ethical dilemma since they knew they were color vision deficient, but accepted the false results on the first FDME. During the investigation, one interviewed applicant stated, "Cheating is an acceptable means to achieve your goals. The honor code is violated only if you get caught."

An applicant correctly identified all 14 PIP plates. However, the first author was suspicious of color vision deficiency during the physical examination due to other testing cues. The PIP plates were shuffled, and the color vision screening was repeated. The applicant then missed 12 of 14 PIP plates and was medically disqualified. A medic in the clinic admitted he coached the color vision

deficient applicant, his friend, on the correct answers to the PIP series before the applicant arrived for his FDME.

Screening trained aviators by inflight evaluation

Several publications discussed the concept of screening inflight evaluation for Army aviators with color vision deficiency discovered after flight training. Army aviators failing PIP and/or FALANT complete inflight evaluations to demonstrate their operational color vision proficiency. The inflight evaluation includes routinely presentations with the control tower Aldis light gun using red, green, and white challenges; and the smoke bomb test using various signal colors, to include white, red, yellow, green, and violet. These tests require objective identification of randomly presented colors with binomial scoring. Some flight surgeons conducting inflight evaluations include testing of color discrimination on map reading, tactical glide slopes, runway lighting, and aircraft beacon lighting. These latter tests are more subjective than the light gun and smoke bomb tests with correct responses learned by flying experiences. The policy is that aviators with color vision deficiency who do not pass these inflight, operational tests will not be given a waiver to continue Army aviation service (Appleton, 1972; Ward et al., 1976; Department of the Army, 1989).

Method

The AEDR flight physical history database, and waiver and suspension files were searched for codes related to color vision deficiencies for the period of calendar years 1982 to 1992. A case was defined as an Army aviator who was discovered to have color vision deficiency after entrance into the aviator training program at Fort Rucker. The aeromedical board documents and AEDR flight physical data were reviewed to confirm the presence of color vision deficiency. The following data elements were extracted from records: patient's name, Social Security number, age at diagnosis, calendar year of diagnosis, aeromedical board disposition for continued flying duties, component of service, and rank. The database contained also the results of pseudoisochromatic plates test (PIP), Farnsworth lantern test (FALANT), control tower light gun test, colored smoke bomb test, Munsell's D-15 and D-100 hue tests, and optometric or ophthalmologic consultations. For calculation of the incidence rates, an estimate of the aviator-years of exposure per calendar year was obtained from AEDR reference tables (Mason and Shannon, 1994).

Results

Table 2 shows the number of new cases of Army aviators with color vision deficiency for calendar years 1982 to 1992, and the incidence of color vision deficiency cases per 1,000 aviator-years by calendar year. The incidence was not calculated for calendar years 1982 to 1985 since there is no known estimate of the aviator-years for these years. About 1 new Army aviator per 10,000 Army aviators per year had color vision deficiency after entrance into flight training. Of the 29

cases, 27 were aviators granted waivers for flying duties, and 2 were exceptions to policy granted to Army aviator students discovered to have color vision deficiency after arrival at Fort Rucker, Alabama, for aviator training.

Table 2.
Incidence of color vision deficiency waivers per 1,000 aviator-years by calendar year.

Color vision deficiency waivers granted	Calendar year										
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Number of new cases	2	2	2	2	8	2	2	1	2	4	2
Incidence	-	-	-	-	0.42	0.09	0.09	0.05	0.09	0.18	0.10

Table 3 shows the findings among the color vision deficient subjects in the study. The age of the aviator at discovery of the color vision deficiency ranged from 23 to 59. All of the subjects failed the PIP screening test. Of the 72 percent (21 of 29) who took the FALANT screening test, all failed the FALANT. The color smoke bomb and tower light gun tests were administered to 55 percent (16 of 29), and all passed. One aviator was given the tower light gun test only, and failed, but was still granted a waiver. Only 55 (16 of 29) percent had ophthalmology or optometry consultation. Only 17 percent (5 of 29) had a basic attempt to discover the axis of their color vision deficiency by use of the D-15 hue test. Four of the five had deuteranopia, the other had protanopia.

Discussion

As expected, since color vision deficient applicants are denied routinely entry into Army aviator flight training, the incidence of color vision deficiency among Army aviators is rare, on the order of 1 new case per 10,000 aviator-years per year. Thus, we presume most of these cases should be acquired color vision deficiency, which is caused usually by a serious underlying visual system disorders or use of medications that can cause retinopathy. Therefore, it is disconcerting to find that only half of the aviators underwent an evaluation by an eye health care professional.

Given that all but one of the aviators with color vision deficiency passed their operational color vision tests (light gun and smoke bomb), we can presume that most of the aviators have anomalous (partial loss) of color vision in their axis of deficiency. Deuteranomalous observers are less prone to colored aviation signal errors than protanomalous observers (Heath and Schmidt, 1959; Kuyk et al., 1987). Fortunately, of our aviators who underwent diagnostic testing (5 of 29), most (4 of 5) had mild to moderate deuteranomalous color vision deficiency, rather than protanomalous color vision deficiency. It would be prudent to conduct diagnostic testing to determine the degree and axis of color vision deficiency in all aviators who fail color vision screening tests.

Table 3.
Findings among the color vision deficient subjects.

Subject	Year of waiver	Age that year	Years of flying after	Component of service	Grade of service	PIP	Falant	Color smoke	Tower lights	D15 test	Ophthalmology/ optometry consult?
1	1982	28	12	Active duty	Warrant	Fail	-	-	-	-	No
2	1982	30	12	Active duty	Warrant	Fail	Fail	Pass	Pass	Deuteranopia	Yes
3	1983	31	11	Active duty	Commissioned	Fail	Fail	Pass	Pass	-	No
4	1983	47	11	Civilian	Civilian	Fail	-	-	-	-	No
5	1984	28	10	Active duty	Commissioned	Fail	-	-	-	-	No
6	1984	31	10	Active duty	Commissioned	Fail	Fail	-	Fail	Deuteranopia	Yes
7	1985	27	8	Active duty	Warrant	Fail	-	-	-	-	No
8	1985	34	2	Active duty	Warrant	Fail	-	-	-	-	No
9	1986	23	8	Active duty	Commissioned	Fail	Fail	Pass	Pass	-	Yes
10	1986	27	6	Active duty	Commissioned	Fail	Fail	Pass	Pass	-	Yes
11	1986	28	8	USAR	Warrant	Fail	Fail	-	-	-	Yes
12	1986	33	2	ARNG	Warrant	Fail	Fail	-	-	-	No
13	1986	34	5	Active duty	Warrant	Fail	-	-	-	-	No
14	1986	36	8	ARNG	Warrant	Fail	Fail	Pass	Pass	-	Yes
15	1986	36	7	ARNG	Warrant	Fail	-	-	-	-	No
16	1986	39	3	Active duty	Commissioned	Fail	Fail	-	-	-	No
17	1987	24	7	Active duty	Commissioned	Fail	Fail	Pass	Pass	-	Yes
18	1987	25	1	Active duty	Warrant	Fail	Fail	Pass	Pass	Deuteranopia	Yes
19	1988	25	6	ARNG	Warrant	Fail	Fail	Pass	Pass	-	Yes
20	1988	43	3	Active duty	Warrant	Fail	Fail	Pass	Pass	-	Yes
21	1989	31	5	Active duty	Warrant	Fail	Fail	Pass	Pass	-	Yes
22	1990	35	4	Active duty	Warrant	Fail	Fail	Pass	Pass	-	No
23	1990	59	1	ARNG	Warrant	Fail	Fail	-	-	Deuteranopia	Yes
24	1991	33	1	Active duty	Commissioned	Fail	-	-	-	-	No
25	1991	43	1	ARNG	Warrant	Fail	Fail	Pass	Pass	-	Yes
26	1991	45	3	ARNG	Warrant	Fail	Fail	Pass	Pass	Protanopia	Yes
27	1991	49	2	Civilian	Civilian	Fail	Fail	Pass	Pass	-	No
28	1992	29	2	Active duty	Commissioned	Fail	Fail	Pass	Pass	-	Yes
29	1992	33	2	Active duty	Warrant	Fail	Fail	Pass	Pass	-	Yes

Conclusions and summary

Chief, Visual Sciences Branch, U.S. Army Aeromedical Research Laboratory, requested a determination of the incidence of color vision deficiency among Army aviators. As we enter the next century, the color vision requirements of Army aviator will increase with the introduction of multicolored displays.

Since aviator training applicants are disqualified routinely from training due to color vision deficiency, there should be no aviators with color vision deficiency. However, this paper details incidents of exception to policy for known color vision deficiency, acquired color vision deficiency, and aviation medicine clinic screening program failures due to poor methods or deception by applicants and conspirators. The inflight evaluation of aviators discovered to have color vision deficiency is described.

The incidence of color vision deficiency was determined by review of records in the U.S. Army Aviation Epidemiology Data Register, to include archived aeromedical board documents, for the period of calendar years 1982 to 1992. Color vision deficiency among Army aviators is rare with an incidence of about 1 new case per 10,000 aviator-years per year. Two of 29 were granted exceptions to policy to complete flight training with color vision deficiency. The others (27 of 29) were granted administrative waivers to continue flying duties with their condition. Only half of the color vision deficient aviators underwent ophthalmology or optometry consultation. Only 17 percent (5 of 29) underwent an attempt to discover the axis of color vision deficiency. Only 59 percent (17 of 29) underwent inflight evaluations, despite the longstanding aeromedical policy requirement for all aviators with color vision deficiency to undergo inflight evaluations.

We recommend the U.S. Army Aeromedical Center continue quality assurance inspections of facilities conducting flying duty medical examinations and repeat color vision screening upon an applicant's arrival at Fort Rucker for flight training. Aviator training applicants with color vision deficiency should be disqualified from entrance into flight training. All Army aviators with color vision deficiency should have complete ocular examinations to rule out underlying disorders, determinations of the degree and axis of their color vision deficiency, and inflight testing of their operational color vision proficiency. Color vision standards should not be changed at this time.

We recommend the USAARL Crew Injury Branch determine if Army aviators with color vision deficiency are at increased risk for aviation mishap. The Visual Sciences Branch should develop computer-oriented color vision testing methods for the flight surgeon office, to include diagnostic modules in the case color vision deficiency is discovered. With the advent of increased color complexity in Army aviation cockpits, color vision performance studies are required to assess the risk for mishap and success of mission completion. These studies may lead to new recommendations for color vision screening standards for Army aviator training applicants.

References

Adams, A. J., and Tague, M. K. 1985. Performance of air traffic control tasks by protanopic color defectives. American journal of optometry and physiological optics. 62:744-750.

Appleton, B. 1972. Predicting color vision performance in aviators. In: Colour vision requirements in different operational roles. Neuilly-sur-Seine, France: Advisory Group on Aerospace Research and Development. AGARD-CP-99, pp. A9-1 to A9-5.

Department of the Army. 1989. Memorandum for all flight surgeons, Subject: Aeromedical policy letter 18-89, color vision deficiencies. Fort Rucker, AL: U.S. Army Aeromedical Center. APL 18-89.

Department of the Army. 1995. Medical fitness standards. Washington, DC: Headquarters, Department of the Army. Army regulation 40-501.

Dille, J. R., and Booze, C. F. 1979. The 1979 accident experience of civilian pilots with static physical defects. Oklahoma City, OK: Civil Aeromedical Institute, Federal Aviation Administration. FAA-AM-79-19.

Ditmars, D. L., and Keener, R. J. 1976. A contact lens for the treatment of color vision defects. Military medicine. 141:319-322.

Farnsworth, D. 1946. Confusion of coloured lights a small subtense by protans and deutans. Croton, CT: U.S. Naval Submarine Medical Research Laboratory. NSMRL Report No. 108.

Hart, W. M. 1992. Alder's physiology of the eye. St. Louis, MO: Mosby-Year Book, Inc.

Heath, G. G., and Schmidt, I. 1959. Signal color recognition by color defective observers. American journal of optometric physiology and optometry. 36:421-437.

Kuyk, T. K., Veres, J. G., Lahey, M. A., and Clark, D. J. 1987. Ability of deutan color defectives to perform simulated air traffic control tasks. American journal of optometry and physiological optics. 64:2-10.

LaBissoniere, P. 1974. The X-Chrom lens. International contact lens clinic. 1:48-55.

Mason, K. T., and Shannon, S. G. 1994. Aviation Epidemiology Data Register: Age distribution of U.S. Army aviators stratified by gender and component of service. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Technical Report No. 94-4.

Mason, K. T. 1995. The FDME administration and AEDR data entry guide for the U.S. Army flight surgeon's office. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Technical Report No. 95-x (in press).

Nathan, J., Henry, G. H., and Cole, B. L. 1964. Recognition of colored road traffic signals by normal and color vision defective observers. Journal of the optical society of America. 54:1041-1045.

Ruff, S., and Schmidt, I. 1940. Ability of color blind persons to distinguish colored signal lights used in aviation. Luftfahrmedizine. 5:53-65.

Sloan, L. L., and Habel, A. 1955a. Color signal systems for the red-green color blind: an experimental test of the three color system proposed by Judd. Journal of the optical society of America. 45:592-598.

Sloan, L. L., and Habel, A. 1955b. Recognition of red green point sources by color deficient observers. Journal of the optical society of America. 45:599-601.

Steen, J., Collins, W. E, and Lewis, M. F. 1973. Utility of several clinical tests of color defective vision in predicting daytime and nighttime performance with the aviation signal light gun. Oklahoma City, OK: Civil Aeromedical Institute, Federal Aviation Administration. FAA-AM-73-18.

Verriest, G., Neubauer, O., Marre, M., and Uvijls, A. 1980. New investigation concerning the relationships between congenital colour vision defects and road traffic security. International ophthalmology. 2:87-99.

Vingrys, A. J., and Cole, B. L. 1988. Are colour vision standards justified for the transport industry? Ophthalmic physiology and optometry. 8:257-274.

Ward, C. L., Barreca, N. E., Kreutzmann, R. J., Click, D. D., and Shamah, M. A. 1976. U.S. Army medical inflight evaluations: 1965 to 1975. In: The use of inflight evaluations for the assessment of aircrew fitness. Neuilly-sur-Seine, France: Advisory Group on Aerospace Research and Development. AGARD-CP-182, pp. B1-1 to B1-11.

Watkins, R. D. 1971. The color vision requirements of civil aircraft pilots. Melbourne, Australia: Department of Civil Aviation. Aviation medicine memorandum No. 29, pp. 1-34.

Welsh, K. W., Vaughan, J. A., and Rasmussen, P. G. 1978. Aeromedical implications of the X-Chrom lens for improving color vision deficiencies. Oklahoma City, OK: Civil Aeromedical Institute, Federal Aviation Administration. FAA-AM-78-22.

Other relevant references not cited

Appleton, B., Wolfe, M. S., and Mishtowt, G. I. 1973. Chloroquine as a malarial suppressive, absence of visual effects. Military medicine. 138:225-226.

Bailey, R. W. 1972. Aircrew color vision requirements, a comparison of accident rates among color defective and normal personnel. In: Colour vision requirements in different operational roles. Neuilly-sur-Seine, France: Advisory Group on Aerospace Research and Development. AGARD-CP-99, pp. A8-1 to A8-4.

Brennan, D. H. Colour vision requirements in different operational roles. In: Colour vision requirements in different operational roles. Neuilly-sur-Seine, France: Advisory Group on Aerospace Research and Development. AGARD-CP-99, pp. A7-1 to A7-4.

Dille, J. R., and Booze, C. F. 1981. The prevalence of visual deficiencies among 1979 general aviation accident airmen. Oklahoma City, OK: Civil Aeromedical Institute, Federal Aviation Administration. FAA-AM-81-14.

Divorine, I. 1963. The importance of color vision in the military services. Optometry weekly. 54:1191-1195.

Easterbrook, M. 1988. Ocular effects and safety of antimalarial agents. Americal journal of medicine. 85:23-29.

Harper, C. R. 1964. Physical defects of civilian pilots related to aircraft accidents. Aerospace medicine. 35:851-856.

Jaanus, S. D. 1992. Ocular side effects of selected systemic drugs. Optometry clinics. 2:73-96.

Jones, K. N., Steen, J., and Collins, W. E. 1975. Predictive validities of several clinical color vision test for aviation signal light gun performance. Oklahoma City, OK: Civil Aeromedical Institute, Federal Aviation Administration. FAA-AM-75-1.

Kahn, H. A., and Sempos, C. T. 1989. Statistical methods in epidemiology. New York City, NY: Oxford University Press.

Lawhill, T., Appleton, B., and Alstatt, L. 1968. Chloroquine accumulation in human eyes. Americal journal of ophthalmology. 65:530-532.

Mertens, H. W. 1990. Evaluation of functional color vision requirements and current color vision screening tests for air traffic control specialists. Oklahoma City, OK: Civil Aeromedical Institute, Federal Aviation Administration. FAA-AM-90-9.

Office of the Chief Surgeon, Air Service. 1921. Statistical report on airplane crashes in the air service during 1920. Air Service information circular. 4(340):4-6.

Steen, J., and Lewis, M. F. 1971. Color defective vision, and day and night recognition of aviation color signal light flashes. Oklahoma City, OK: Civil Aeromedical Institute, Federal Aviation Administration. FAA-AM-71-32.

Initial distribution

Commander, U.S. Army Natick Research,
Development and Engineering Center
ATTN: SATNC-MIL (Documents
Librarian)
Natick, MA 01760-5040

Chairman
National Transportation Safety Board
800 Independence Avenue, S.W.
Washington, DC 20594

Commander
10th Medical Laboratory
ATTN: Audiologist
APO New York 09180

Naval Air Development Center
Technical Information Division
Technical Support Detachment
Warminster, PA 18974

Commanding Officer, Naval Medical
Research and Development Command
National Naval Medical Center
Bethesda, MD 20814-5044

Deputy Director, Defense Research
and Engineering
ATTN: Military Assistant
for Medical and Life Sciences
Washington, DC 20301-3080

Commander, U.S. Army Research
Institute of Environmental Medicine
Natick, MA 01760

Library
Naval Submarine Medical Research Lab
Box 900, Naval Sub Base
Groton, CT 06349-5900

Executive Director, U.S. Army Human
Research and Engineering Directorate
ATTN: Technical Library
Aberdeen Proving Ground, MD 21005

Commander
Man-Machine Integration System
Code 602
Naval Air Development Center
Warminster, PA 18974

Commander
Naval Air Development Center
ATTN: Code 602-B
Warminster, PA 18974

Commanding Officer
Armstrong Laboratory
Wright-Patterson
Air Force Base, OH 45433-6573

Director
Army Audiology and Speech Center
Walter Reed Army Medical Center
Washington, DC 20307-5001

Commander/Director
U.S. Army Combat Surveillance
and Target Acquisition Lab
ATTN: SFAE-IEW-JS
Fort Monmouth, NJ 07703-5305

Director
Federal Aviation Administration
FAA Technical Center
Atlantic City, NJ 08405

Director
Walter Reed Army Institute of Research
Washington, DC 20307-5100

Commander, U.S. Army Test
and Evaluation Command
Directorate for Test and Evaluation
ATTN: AMSTE-TA-M (Human Factors
Group)
Aberdeen Proving Ground,
MD 21005-5055

Naval Air Systems Command
Technical Air Library 950D
Room 278, Jefferson Plaza II
Department of the Navy
Washington, DC 20361

Director
U.S. Army Ballistic
Research Laboratory
ATTN: DRXBR-OD-ST Tech Reports
Aberdeen Proving Ground, MD 21005

Commander
U.S. Army Medical Research
Institute of Chemical Defense
ATTN: SGRD-UV-AO
Aberdeen Proving Ground,
MD 21010-5425

Commander
USAMRMC
ATTN: SGRD-RMS
Fort Detrick, Frederick, MD 21702-5012

HQ DA (DASG-PSP-O)
5109 Leesburg Pike
Falls Church, VA 22041-3258

Harry Diamond Laboratories
ATTN: Technical Information Branch
2800 Powder Mill Road
Adelphi, MD 20783-1197

U.S. Army Materiel Systems
Analysis Agency
ATTN: AMXSY-PA (Reports Processing)
Aberdeen Proving Ground
MD 21005-5071

U.S. Army Ordnance Center
and School Library
Simpson Hall, Building 3071
Aberdeen Proving Ground, MD 21005

U.S. Army Environmental
Hygiene Agency
ATTN: HSHB-MO-A
Aberdeen Proving Ground, MD 21010

Technical Library Chemical Research
and Development Center
Aberdeen Proving Ground, MD
21010-5423

Commander
U.S. Army Medical Research
Institute of Infectious Disease
ATTN: SGRD-UIZ-C
Fort Detrick, Frederick, MD 21702

Director, Biological
Sciences Division
Office of Naval Research
600 North Quincy Street
Arlington, VA 22217

Commandant
U.S. Army Aviation
Logistics School ATTN: ATSQ-TDN
Fort Eustis, VA 23604

Headquarters (ATMD)
U.S. Army Training
and Doctrine Command
ATTN: ATBO-M
Fort Monroe, VA 23651

IAF Liaison Officer for Safety
USAF Safety Agency/SEFF
9750 Avenue G, SE
Kirtland Air Force Base
NM 87117-5671

Naval Aerospace Medical
Institute Library
Building 1953, Code 03L
Pensacola, FL 32508-5600

Command Surgeon
HQ USCENTCOM (CCSG)
U.S. Central Command
MacDill Air Force Base, FL 33608

Director
Directorate of Combat Developments
ATTN: ATZQ-CD
Building 515
Fort Rucker, AL 36362

U.S. Air Force Institute
of Technology (AFIT/LDEE)
Building 640, Area B
Wright-Patterson
Air Force Base, OH 45433

Henry L. Taylor
Director, Institute of Aviation
University of Illinois-Willard Airport
Savoy, IL 61874

Chief, National Guard Bureau
ATTN: NGB-ARS
Arlington Hall Station
111 South George Mason Drive
Arlington, VA 22204-1382

AAMRL/HEX
Wright-Patterson
Air Force Base, OH 45433

Commander
U.S. Army Aviation and Troop Command
ATTN: AMSAT-R-ES
4300 Goodfellow Bouvelard
St. Louis, MO 63120-1798

U.S. Army Aviation and Troop Command
Library and Information Center Branch
ATTN: AMSAV-DIL
4300 Goodfellow Boulevard
St. Louis, MO 63120

Federal Aviation Administration
Civil Aeromedical Institute
Library AAM-400A
P.O. Box 25082
Oklahoma City, OK 73125

Commander
U.S. Army Medical Department
and School
ATTN: Library
Fort Sam Houston, TX 78234

Commander
U.S. Army Institute of Surgical Research
ATTN: SGRD-USM
Fort Sam Houston, TX 78234-6200

Air University Library
(AUL/LSE)
Maxwell Air Force Base, AL 36112

Product Manager
Aviation Life Support Equipment
ATTN: SFAE-AV-LSE
4300 Goodfellow Boulevard
St. Louis, MO 63120-1798

Commander and Director
USAE Waterways Experiment Station
ATTN: CEWES-IM-MI-R,
CD Department
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Commanding Officer
Naval Biodynamics Laboratory
P.O. Box 24907
New Orleans, LA 70189-0407

Assistant Commandant
U.S. Army Field Artillery School
ATTN: Morris Swott Technical Library
Fort Sill, OK 73503-0312

Mr. Peter Seib
Human Engineering Crew Station
Box 266
Westland Helicopters Limited
Yeovil, Somerset BA20 2YB UK

U.S. Army Dugway Proving Ground
Technical Library, Building 5330
Dugway, UT 84022

U.S. Army Yuma Proving Ground
Technical Library
Yuma, AZ 85364

AFFTC Technical Library
6510 TW/TSTL
Edwards Air Force Base,
CA 93523-5000

Commander
Code 3431
Naval Weapons Center
China Lake, CA 93555

Aeromechanics Laboratory
U.S. Army Research and Technical Labs
Ames Research Center, M/S 215-1
Moffett Field, CA 94035

Sixth U.S. Army
ATTN: SMA
Presidio of San Francisco, CA 94129

Commander
U.S. Army Aeromedical Center
Fort Rucker, AL 36362

Strughold Aeromedical Library
Document Service Section
2511 Kennedy Circle
Brooks Air Force Base, TX 78235-5122

Dr. Diane Damos
Department of Human Factors
ISSM, USC
Los Angeles, CA 90089-0021

U.S. Army White Sands
Missile Range
ATTN: STEWS-IM-ST
White Sands Missile Range, NM 88002

Director, Airworthiness Qualification Test
Directorate (ATTC)
ATTN: STEAT-AQ-O-TR (Tech Lib)
75 North Flightline Road
Edwards Air Force Base, CA 93523-6100

Ms. Sandra G. Hart
Ames Research Center
MS 262-3
Moffett Field, CA 94035

Commander
USAMRMC
ATTN: SGRD-UMZ
Fort Detrick, Frederick, MD 21702-5009

Commander
U.S. Army Health Services Command
ATTN: HSOP-SO
Fort Sam Houston, TX 78234-6000

U. S. Army Research Institute
Aviation R&D Activity
ATTN: PERI-IR
Fort Rucker, AL 36362

Commander
U.S. Army Safety Center
Fort Rucker, AL 36362

U.S. Army Aircraft Development
Test Activity
ATTN: STEBG-MP-P
Cairns Army Air Field
Fort Rucker, AL 36362

Commander
USAMRMC
ATTN: SGRD-PLC (COL R. Gifford)
Fort Detrick, Frederick, MD 21702

TRADOC Aviation LO
Unit 21551, Box A-209-A
APO AE 09777

Netherlands Army Liaison Office
Building 602
Fort Rucker, AL 36362

British Army Liaison Office
Building 602
Fort Rucker, AL 36362

Italian Army Liaison Office
Building 602
Fort Rucker, AL 36362

Directorate of Training Development
Building 502
Fort Rucker, AL 36362

Chief
USAHEL/USAAVNC Field Office
P. O. Box 716
Fort Rucker, AL 36362-5349

Commander, U.S. Army Aviation Center
and Fort Rucker
ATTN: ATZQ-CG
Fort Rucker, AL 36362

Dr. Sehchang Hah
Dept. of Behavior Sciences and
Leadership, Building 601, Room 281
U. S. Military Academy
West Point, NY 10996-1784

Canadian Army Liaison Office
Building 602
Fort Rucker, AL 36362

German Army Liaison Office
Building 602
Fort Rucker, AL 36362

French Army Liaison Office
USAAVNC (Building 602)
Fort Rucker, AL 36362-5021

Australian Army Liaison Office
Building 602
Fort Rucker, AL 36362

Dr. Garrison Rapmund
6 Burning Tree Court
Bethesda, MD 20817

Commandant, Royal Air Force
Institute of Aviation Medicine
Farnborough, Hampshire GU14 6SZ UK

Defense Technical Information
Cameron Station, Building 5
Alexandra, VA 22304-6145

Commander, U.S. Army Foreign Science
and Technology Center
AIFRTA (Davis)
220 7th Street, NE
Charlottesville, VA 22901-5396

Commander
Applied Technology Laboratory
USARTL-ATCOM
ATTN: Library, Building 401
Fort Eustis, VA 23604

Commander, U.S. Air Force
Development Test Center
101 West D Avenue, Suite 117
Eglin Air Force Base, FL 32542-5495

Aviation Medicine Clinic
TMC #22, SAAF
Fort Bragg, NC 28305

Dr. H. Dix Christensen
Bio-Medical Science Building, Room 753
Post Office Box 26901
Oklahoma City, OK 73190

Commander, U.S. Army Missile
Command
Redstone Scientific Information Center
ATTN: AMSMI-RD-CS-R
/ILL Documents
Redstone Arsenal, AL 35898

Aerospace Medicine Team
HQ ACC/SGST3
162 Dodd Boulevard, Suite 100
Langley Air Force Base,
VA 23665-1995

U.S. Army Research and Technology
Laboratories (AVSCOM)
Propulsion Laboratory MS 302-2
NASA Lewis Research Center
Cleveland, OH 44135

Commander
USAMRMC
ATTN: SGRD-ZC (COL John F. Glenn)
Fort Detrick, Frederick, MD 21702-5012

Dr. Eugene S. Channing
166 Baughman's Lane
Frederick, MD 21702-4083

U.S. Army Medical Department
and School
USAMRDALC Liaison
ATTN: HSMC-FR
Fort Sam Houston, TX 78234

NVESD
AMSEL-RD-NV-ASID-PST
(Attn: Trang Bui)
10221 Burbeck Road
Fort Belvior, VA 22060-5806

CA Av Med
HQ DAAC
Middle Wallop
Stockbridge, Hants S020 8DY UK

Dr. Christine Schlichting
Behavioral Sciences Department
Box 900, NAVUBASE NLON
Groton, CT 06349-5900

Commander
Aviation Applied Technology Directorate
ATTN: AMSAT-R-TV
Fort Eustis, VA 23604-5577

COL Yehezkel G. Caine, MD
Surgeon General, Israel Air Force
Aeromedical Center Library
P. O. Box 02166 I.D.F.
Israel

HQ ACC/DOHP
205 Dodd Boulevard, Suite 101
Langley Air Force Base,
VA 23665-2789

41st Rescue Squadron
41st RQS/SG
940 Range Road
Patrick Air Force Base,
FL 32925-5001

48th Rescue Squadron
48th RQS/SG
801 Dezonia Road
Holloman Air Force Base,
NM 88330-7715

HQ, AFOMA
ATTN: SGPA (Aerospace Medicine)
Bolling Air Force Base,
Washington, DC 20332-6128

ARNG Readiness Center
ATTN: NGB-AVN-OP
Arlington Hall Station
111 South George Mason Drive
Arlington, VA 22204-1382

35th Fighter Wing
35th FW/SG
PSC 1013
APO AE 09725-2055

66th Rescue Squadron
66th RQS/SG
4345 Tyndall Avenue
Nellis Air Force Base, NV 89191-6076

71st Rescue Squadron
71st RQS/SG
1139 Redstone Road
Patrick Air Force Base,
FL 32925-5000

Director
Aviation Research, Development
and Engineering Center
ATTN: AMSAT-R-Z
4300 Goodfellow Boulevard
St. Louis, MO 63120-1798

Commander
USAMRMC
ATTN: SGRD-ZB (COL C. Fred Tyner)
Fort Detrick, Frederick, MD 21702-5012

Commandant
U.S. Army Command and General Staff
College
ATTN: ATZL-SWS-L
Fort Levenworth, KS 66027-6900

Director
Army Personnel Research Establishment
Farnborough, Hants GU14 6SZ UK

Dr. A. Kornfield
895 Head Street
San Francisco, CA 94132-2813

Mr. George T. Singley, III
Depupty Assistant Secretary of the Army
for Research and Technology
and Chief Scientist
ATTN: Room 3E374
103 Army Pentagon
Washington, DC 20310-0103

The Honorable Gilbert F. Decker
Assistant Secretary of the Army
for Research, Development,
and Acquisition
ATTN: Room 2E672
103 Army Pentagon
Washington, DC 20310-0103

Dr. Craig Dorman
Office of the Deputy Director,
Defense Research and Engineering
ATTN: Room 3D129LM
103 Army Pentagon
Washington, DC 20310-0103

HQ, AFOMA
ATTN; SGPA (Aerospace Medicine)
Bolling Air Force Base,
Washington, DC 20332-6188

Cdr, PERSCOM
ATTN: TAPC-PLA
200 Stovall Street, Rm 3N25
Alexandria, VA 22332-0413